PPPL to design a high-resolution diagnostic system for the National Ignition Facility

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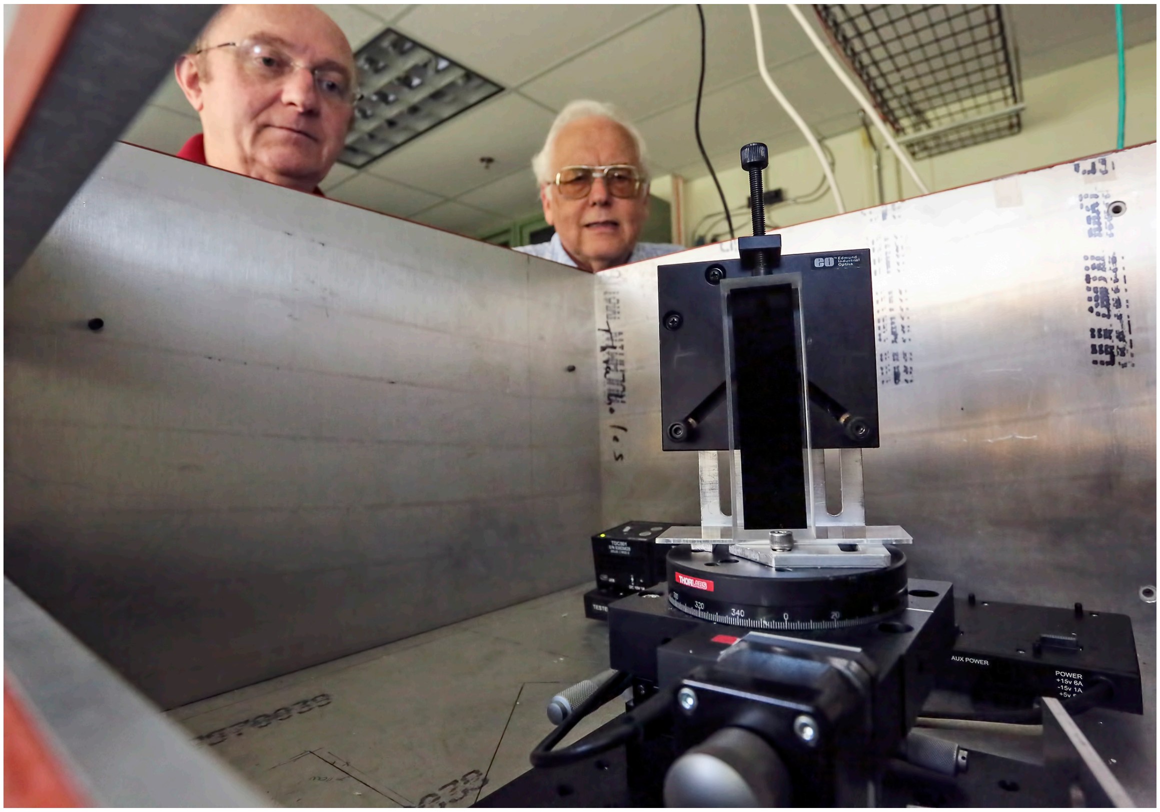

Kenneth Hill and Manfred Bitter inspect an X-ray crystal spectrometer to be used to study OMEGA EP laser-produced plasmas. (Photo by Elle Starkman/Office of Communications)

Two U.S. Department of Energy (DOE) laboratories working on very different types of fusion experiments have begun a novel collaboration. Under the arrangement, the DOE's Princeton Plasma Physics Laboratory (PPPL) will design a diagnostic system to provide high-resolution analysis of research on the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory (LLNL). This work is supported by the DOE Office of Science and LLNL.

NIF is the world's most energetic laser. NIF is funded by the National Nuclear Security Administration (NNSA), the agency charged with ensuring our nation's nuclear security. The chief mission of NIF is to provide experimental insight and data for NNSA's science-based Stockpile Stewardship Program in the area of high-energy-density physics, a scientific field of direct relevance to nuclear deterrence and national nuclear security.

PPPL has used such diagnostic systems, called X-ray crystal spectrometers, for decades to study the data from the laboratory's magnetic fusion research. These experiments heat electrically charged plasma to tens of millions of degrees Celsius and confine it with magnetic fields to make the atomic nuclei — or ions — in the plasma merge and release their energy.

High-power lasers

NIF, by contrast, is developing a technique called inertial confinement fusion that is quite different. NIF fires 192 high-power lasers at tiny pellets of fuel to compress the target, thereby heating the plasma and causing the ions inside it to fuse. The PPPL spectrometer will analyze and record the data from these NIF experiments in high-resolution detail. Spectrometers now in use at NIF have lower resolution.

Creating the new spectrometer are physicists Kenneth Hill and Manfred Bitter, whose diagnostic designs are used in magnetic fusion experiments around the world.

"This is basically PPPL expanding its diagnostic equipment into high-energy-density physics," said Phil Efthimion, head of the PPPL Plasma Science and Technology Department. "Ken and Manfred have the experience and knowledge to take the technology they developed more than 20 years ago and extend it to the very bright and high-energy X-rays that NIF produces."

The spectrometer the two physicists are designing will fit into tight quarters. While the NIF lasers are housed in a building the size of three football fields, the pellet at which they aim is only a millimeter in diameter, or about 4 hundredths of an inch. The target shrinks to one-tenth of a millimeter when struck by the beams. To stay clear of the beams while recording the data, the spectrometer will be positioned in a narrow chamber and set inside a holder that is less than a foot in diameter.

Part of a multi-pronged effort

This research is part of a multi-pronged effort in the ongoing inertial confinement (ICF) program, which is used to study ignition and burn in a laboratory setting, and which aims to tackle arguably the most challenging observable condition in ICF implosions—stagnation, the termination of the compression process before fusion takes place. The spectrometer will be used to identify the quantitative character of the implosion as it "stagnates" over a small volume for the very first time.

The spectrometer, which could be completed next fall, will collect data from ICF and other experiments to be conducted at NIF. For example, geophysicists studying the intense density and pressure at the core of the Earth will be able to use the NIF lasers to create laboratory conditions that produce similar extreme states of matter.

The spectrometer for NIF will be the second for high-energy-density physics that Hill and Bitter have designed. They previously collaborated in designing an X-ray crystal spectrometer, and evaluated one of the precision spherically bent crystals to be used in the spectrometer, for the OMEGA-EP laser system at the University of Rochester, which supports inertial confinement research. This spectrometer will now undergo a final design review, with testing and initial physics measurements on OMEGA scheduled for early 2016.

PPPL, on Princeton University's Forrestal Campus in Plainsboro, N.J., is devoted to creating new knowledge about the physics of plasmas — ultra-hot, charged gases — and to developing practical solutions for the creation of fusion energy. Results of PPPL research have ranged from a portable nuclear materials detector for counterterrorism use, to universally employed computer codes for analyzing and predicting the outcome of fusion experiments. The Laboratory is managed by the university for the U.S. Department of Energy's Office of Science, which is the largest single supporter of basic research in the physical sciences in the United States, and is working to address some of the most pressing challenges of our time. For more information, please visit science.energy.gov.

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Established by Congress in 2000, NNSA is a semi-autonomous agency within DOE responsible for enhancing national security through the military application of nuclear science. NNSA maintains the safety, security, and effectiveness of the U.S. nuclear weapons stockpile without nuclear explosive testing; works to reduce global danger from weapons of mass destruction; provides the U.S. Navy with safe and effective nuclear propulsion; and responds to nuclear and radiological emergencies in the U.S. and abroad.